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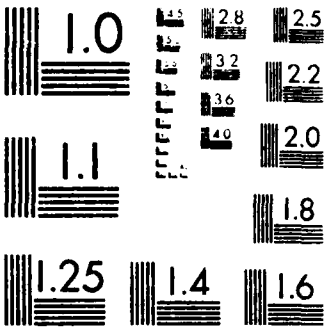

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DESIGN, TEST, and EVALUATION of an AIR FORCE ENVIRONMENTAL MODEL and DATA EXCHANGE

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APRIL 1984

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SEPTEMBER 1982 - SEPTEMBER 1983

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AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

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This report documents development of a prototype computer system designed to assist environmental quality staff at an Air Force major command. The computer system, an integration of current technology, permits error-free data entry and high-speed processing for modeling, simulation studies, and network operations. Functionally designed to meet novice user requirements, the multiuser system can be inexpensively expanded to accomodate larger workloads. The capabilities of the prototype system meet data base extraction requirements for capture and subsequent manipulation of

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20. mation and environmental quality data needed to perform environmental assessments. The prototype can serve as a test bed for lead-in applications, locally defined processing, and network operations.

PREFACE

This report was prepared by Applied Modeling Incorporated, 6355 Topanga Canyou Boulevard, Suite 433, Woodland Hills, California 91367 under contract F41689-82-C-0068 for the Air Force Engineering and Services Center (AFESC/RD), Engineering and Services Laboratory, Tyndall Air Force Base, Florida 32403. Efforts documented in this report were performed between September 1982 and September 1983. Captain Glenn E. Tapio was the AFESC/RDVW Project Officer.

The assistance and contribution by Headquarters Air Training Command, Randolph Air Force Base, Texas made the fielding of this prototype system possible. Especially significant to the application of this prototype were the efforts of HQ ATC/DEV staff, notably Mr. Tracy Smith, Mr. Carl Lahser, and Captain Jaime Cantu. While the trials of institutionalizing this prototype are unique to ATC, the lessons learned will be invaluable as similar computer capabilities are extended to other Air Force agencies.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

GLENN E. TAPIO, Capt, USAF
Project Officer

ROBERT E. BOYER, Col, USAF
Director, Engineering and Services Laboratory

JIMMY W. FULFORD, Lt Col, USAF
Chief, Environics Division

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SECTION I

INTRODUCTION

This document is the final report of the design, test and evaluation of a computerized environmental information system by Applied Modeling, Inc. (AMI). The tested system establishes the groundwork for the development of an Air Force Environmental Model and Data Exchange (AFEMDEX). This report is performed under contract to the Air Force Engineering and Services Center (AFESC).

Interviews and a questionnaire survey conducted at USAF Bases during June 1981 have established a clear and urgent need in the Air Force for better access to environmental information and analytical techniques. To alleviate these deficiencies, a prototype AFEMDEX computer system has been developed and tested for 3 months at the Headquarters Air Training Command Environmental Planning Office (ATC/DEV), Randolph AFB, Texas. The system testing has been conducted by demonstration of environmental data bases and simulation models which satisfy the practical environmental needs of a major command environmental planning office such as HQ ATC/DEV.

The AFEMDEX prototype computer system was developed to streamline multiuser interaction with remote data sources and computerized information resources. The prototype system, as installed at Randolph AFB, is the product of unique layout to effectively apply computer resources in meeting the mission needs of an environmental planning staff. The prototype system was designed to make future adaptation and expansion a simple task.

The objective of this report is to document the design of the prototype AFEMDEX computer system, its testing at ATC/DEV, and an evaluation of its effectiveness. Recommendations for

system improvement and transfer to other Air Force Major commands are also included in this report.

This report is organized into five major sections and one appendix. Section II describes the hardware and software of the prototype AFEMDEX computer system. Section III documents the system testing and an evaluation of the system design, subscribed environmental information data bases and application programs. Major findings are provided in Section IV. Recommendations for system improvement and technology transfer are given in Section V. Finally, Appendix A contains a detailed cost estimate of computer systems similar to the prototype AFEMDEX system.

SECTION II

SYSTEM DEVELOPMENT

A number of planning meetings with the AFESC Project Officer and USAF environmental planning personnel have been conducted at Randolph AFB. The objectives of these meetings were to: (1) review specific HQ ATC/DEV needs and requirements; (2) identify existing Air Force, government and commercial information systems (including environmental models and data bases) which will enhance DEV capabilities; and (3) develop cost-effective computer hardware/software designs. Hardware/software components of the AFEMDEX system are described in the following sections.

A. SYSTEM HARDWARE

The AFEMDEX system is based on a high-performance and modular microcomputer. Major hardware components of this computer include:

- Zendex ZX-86 single-board computer (SBC) with a 16-bit microprocessor (Intel 8086) and a numeric processor (Intel 8087);
- a Quantum 2040 Winchester hard disk with 42 Megabytes (MB) of data storage;
- two Shugart SA-860 8-inch floppy drives with two MB of data storage;
- a Micro-Memory MM-8086E memory board with 512 Kilobytes (KB) dynamic error-correction RAM;
- a Cipher 9-track, 1600 BPI tape drive which can handle 2400-foot reels;
- a Siemens ink jet printer which can output at 270 characters per second;

- a Qume QVT-102 terminal;
- a Prentice 300-bit per second (baud) modem;
- two Hayes 300/1200-baud, auto-dial smart modems;
- two Intel 534 communication boards with 8 serial I/O ports;
- an Intel 215 Winchester disk controller;
- an Intel 218 flexible disk controller;
- a CPC tape-drive controller;
- power supply;
- system chassis;
- a 19-inch rack.

The AFEMDEX computer system is designed to be modular so that additional peripheral equipment can be attached. At the present time, the system can support nine terminals. If more terminals are needed, additional Intel 534 communication boards can be added.

B. SYSTEM SOFTWARE

The AFEMDEX system is based on the iRMX 86 operating system developed by Intel Corporation. This multiuser and multitasking operating system can also be modified to support new or additional hardware.

The AFEMDEX system also includes the following Intel software packages:

EDIT The standard iRMX editor.

ASM86 The 8086/8087/8088 macroassembler.

PLM86 The PL/M-86 compiler.

LINK The 8086 Linker, which combines individual object

modules into a single, relocatable object module.

FORTRAN-86 A FORTRAN compiler that includes FORTRAN-77 language features.

C. APPLICATION SOFTWARE

Applied Modeling, Inc. (AMI) has developed a library of application software programs for the AFMEDEX system. These programs were developed and tested at Randolph AFB. The AFEMDEX library includes programs for systems operations (e.g., network communication) and specific DEV environmental planning needs. Objectives of existing AFEMDEX application programs are summarized below:

1. NETWORK

This program is an asynchronous communication software package used to link the AFEMDEX computer system with an external system. It also allows transferring files between two computers.

2. SPILL

The SPILL program is based upon empirical formulas developed at AFESC. This model calculates the area and quantity of hazardous liquid material spilled on porous and nonporous surfaces. The program contains over 40 different hazardous substances.

3. APIP

This program contains the Air Pavement Improvement Plan for the airbases under the control of HQ/ATC. The program allows the information to be sorted by base, year, condition, and factor. The results are ranked according to priority number.

4. MCP

The title of this program is Military Construction Plan

budget analysis. This program provides a sort routine for base, date, and FTAB number. It also provides budget totals of all sorted material.

5. NPDES

The NPDES (National Pollution Discharge Emissions System) program allows sorting by date, between dates, and source number for groups of source numbers, or any combination of the above. Once sorted, the program calculates the emissions released by the designated sources. NPDES also calculates the average pH, temperature, and flow in millions of gallons per day, and provides updating capabilities.

6. SUPPLY LOG

SUPPLY LOG maintains a listing of equipment that is distributed nationwide by Randolph AFB. The program allows sorting by a variety of categories and code numbers and provides a simple method of updating or making changes to the list.

The AFEMDEX software library also includes the following air quality models of the EPA'S UNAMAP series:

7. PTMAX

An interactive program that analyzes the maximum short-term concentrations from a single point source as a function of stability and wind speed. The final plume height is used for each computation.

8. PTDIS

An interactive program that estimates short-term concentrations directly downwind of a point source at distances specified by the user. The effect of limiting vertical dispersion by a mixing height can be included and gradual plume rise to the point of final rise is also considered. An option allows the calculations of isopleth half-widths for specific concentrations at each downwind distance.

9. PTMTP

An interactive program that estimates, at or above ground level, the concentration from a number of point sources at a number of arbitrarily located receptor points. Plume rise is determined for each source. Downwind and crosswind distances are determined for each source-receptor pair. Concentrations at a receptor from various sources are assumed to be additive. Hourly meteorological data are used; both hourly concentrations and averages over any averaging time from 1-24 hours can be obtained.

10. CRSTER

The Single-Source (CRSTER) Model is designed to calculate the contributions from multiple elevated stack emissions at a plant location to ambient air quality levels, defined in the same time scales as the National Ambient Air Quality Standards. The program calculates concentrations for an entire year and prints out the highest and second-highest 1-hour, 3-hour and 24-hour, as well as annual, mean concentrations at a set of 180 receptors surrounding the plant. The Single-Source (CRSTER) Model is based on a modified form of the Gaussian plume equation which uses empirical dispersion coefficients and includes adjustments for plume rise, limited mixing height and elevated terrain. Pollutant concentrations are computed from measured hourly values of wind speed and direction, and estimated hourly values of atmospheric stability and mixing height.

SECTION III

SYSTEM TESTING AND EVALUATION

In accordance with the contract, AMI posted an analyst at the DEV System Support Office, Randolph AFB, from July 5 to October 11, 1983. AMI's analyst provided testing and training on system hardware and software to DEV personnel in accomplishing daily operational requirements.

During the test and evaluation period the analyst documented over a 95 percent residence time at the DEV System Support Office. The analyst also documented log-ins, usage duration, usage changes, brief explanation of usage requirements and initiator, and all instances of system nonavailability with reasons for same.

The analyst maintained weekly telephone contact with the AFESC Project Officer. This contact provided the project officer with detailed information about system problem areas, planned modifications and other pertinent information.

A. TRAINING

To begin the testing period, three orientation meetings were conducted by AMI's analyst; each lasting approximately 1.5 hours. The orientation covered the basic operation procedures of the AFEMDEX system. During the testing period at Randolph AFB, approximately 22 persons were given the basic orientation training.

The initial hands-on experience began with the use of the AFEMDEX system to communicate with the U.S. Army Construction Engineering Research Laboratory (CERL) computer resources. This UNIX-based computer is one of the systems available to the Air

Force containing numerous potentially usable programs. The main programs of interest are part of the Environmental Technical Information System (ETIS). The ATC/DEV staff spent considerable effort learning and using the ETIS programs. Eight individuals were given hands-on training in the use of the AFEMDEX system, specifically the text editor EDIT, modem operation and basic system operational controls. Emphasis was placed on the use of the line editor which allows programs to be updated, changed, and created. A problem encountered in the editor training was lack of familiarity with a line editor. Several individuals had been exposed to a full-page editor, which is more flexible than the line editor on the system. All individuals were able to pick up the basics of the editor within 3 to 6 hours.

Once the individual understood the editor, he was given instruction on the operating system, covering only the basic information necessary to allow access to the AFEMDEX without the aid of an operator.

Two individuals were given detailed instruction on the use of the AFEMDEX operating system that would enable them to serve as system operator.

B. NETWORKING

One of the primary uses of the AFEMDEX system during the test period was its networking capabilities. AMI's analyst instructed DEV personnel in the methods and techniques to be used in accessing approved subscription systems. The analyst also provided instruction on the applications of various systems to support daily ATC requirements. To assist ATC staff the analyst maintained a reference book which contains access codes and procedures and system operation information. He also summarized user guides and documented numerous miscellaneous items pertinent to the system operation.

During the test period, DEV personnel used the AFEMDEX system to access external systems such as the VAX computer located at CERL and the CDC computer at Tyndall AFB. Network communication proved to be cost effective. Once the desired information was found in an outside system, it was accessed and printed and/or stored in the AFEMDEX system for further evaluation. Such a capability has obvious benefits. The outside system must only be accessed once to get needed data or information; all future work with the data can be done directly on AFEMDEX, rather than on-line with the outside computer. This feature provides substantial cost savings to the Air Force by significantly reducing the amount of time spent on-line with outside computers. This type of usage was the predominant application of the AFEMDEX system for the first 2 months of testing.

Another tested networking capability of the AFEMDEX system was the ability of outside users to dial into the AFEMDEX system, just as one would dial into a large mainframe computer. The outside user's terminal was capable of creating data files, programs, text files and accessing the same on the AFEMDEX. To provide security, access to files was controlled by the system operator who designated which outside or internal users could have access to the system and its files.

C. SYSTEM DESIGN

The AFEMDEX System performed effectively and efficiently during the test period. The system demonstrated the cost and benefits of accessing large systems to retrieving files and data, which can then be manipulated directly on AFEMDEX; this networking capability eliminated costly telephone and computer hookup time. In addition, local users with their own remote terminal could used these same files and data at no charge by

simply tying into the AFEMDEX by telephone modem. However, it was recommended that the remote terminals be maintained within the same geographical area of the central unit to eliminate long-distance telephone charges, whenever possible.

D. EVALUATION OF SYSTEMS SUBSCRIBED

During the test period the major subscribed system used was the CERL Environmental Technical Information System (ETIS). ATC/DEV staff spent many hours learning and using the various programs within ETIS. From this usage it was discovered that ETIS lacks up-to-date information and sufficient detail necessary for ATC/DEV evaluation. For example, the Computer-Aided Legislative Data System (CELDS) contained legislation only down to the state level and did not contain local legislation and regulations that affect ATC. Another example is the program that contained names of key personnel within the different governmental agencies. The latest entries were more than a year old and thus considered out of date. In addition, it was found that the Army orientation of the program applications made many inappropriate for ATC/DEV use. An example is the Environmental Impact Computer System (EICS), which is oriented toward ground operations, and does not address airborne operations.

E. EVALUATION OF PROGRAMS

One of the primary objectives of having AMI staff on site was to adapt existing programs to operate on the AFEMDEX system. However, several problems reduced AMI's effectiveness in attaining this objective.

The primary problem was the inability of ATC/DEV personnel to identify existing computer programs that could be used. The same situation applied to data bases that could be used by

ATC/DEV. AMI attributes these problems mainly to ATC/DEV unfamiliarity with computer systems and computer applications. AMI obtained several lists of potential data bases that could be used by ATC; unfortunately access to these systems could not be obtained during the test period.

AMI was directed to convert the UNAMAP air quality models to the AFEMDEX system. This was before AMI's analyst visited Randolph AFB. The USAF OEHL staff was the primary users of the UMAMAP models via telephone and at Randolph AFB, and conducted several sample runs during the test period. More extensive use is anticipated in the future.

AMI's analyst prepared several programs during the test period, based on specific needs expressed by ATC personnel. Each of these programs is briefly described in the Application Software Section. Because these programs were prepared specifically for ATC, it was expected that a higher benefit would result. These programs should reduce the turnaround time for preparing needed reports, thus creating time and manpower savings. Because the exact usage of these programs is unknown, it is impractical to estimate the specific cost effectiveness. An estimated 20 to 80 percent time saving is expected.

F. SYSTEM USER SENSITIVITY

Determining the user sensitivity is rather subjective, depending on the user's past experience and exposure to computer systems. As most staff members were hesitant to try a new computer system, the analyst was methodical in presenting and assisting users. This aid included defining user requirements and over-the-shoulder supervision of computer sessions.

Those users that had never used a computer before had difficulty in recalling the numerous commands necessary to operate the system. With personnel tutoring and hands-on

experience, most users were able to overcome these early difficulties.

Users with some computer experience found the operating system to be similar to other systems.

One of the major problems encountered was not with the AFEMDEX system, but rather the programs that were used. In many cases the programs were not error-protected. That makes their use difficult when errors were made while inputing data; the program failed when inconsistent data was encountered. Another problem encountered was the lack of documentation, or difficulty of using documentation for these programs.

Some users found the system insensitive because it required the user to be very precise and accurate when communicating with the operating system. These users judged that the system should give more direction on what to do next and be more flexible on acceptance of inputs.

The individuals trained as operators found the system easy to use after the basic commands had been understood and memorized.

While many aspects of the systems programming were specially integrated, the design of AFEMDEX software emphasized the user-friendliness and ease of operation. AMI has modified the application software programs and the operating system to provide error messages and a variety of prompts to assist the user when errors are made.

G. TEST AND EVALUATION SEQUENCE FOR OTHER ENVIRONMENTAL INFORMATION SYSTEMS AND MODELING PROGRAMS.

To assist ATC/DEV in testing and evaluating other environmental information systems and subscriber systems, AMI has

developed an online questionnaire procedure, consisting of a series of 13 questions. If a question is answered "yes," it is worth one point or given the point value designated in the question. The higher the point score, the greater the expectation that the system will be usable by ATC. The questionnaire is presented in Figure 1.

CRITERIA FOR EVALUATING USEFULNESS OF SUBSCRIBER SYSTEMS

* Does the operating system provide current documentation?
* How often is the operating system updated?
  -less than 6 months = 1 ; greater than 6 mos. = 0
* How often is the debugging maintenance done?
  -less than 6 mos. = 1 ; greater than 6 mos. = 0
* Are the programs documented and user manuals available?
* Does the system have user support available?
* Are the programs written in a language that is compatible with AFEMDEX? FORTRAN?
* Does the program perform the analysis or provide the service needed?
* Will the program require conversion to operate on AFEMDEX?
* Are the methodologies used in the programs the best available?
* Are the programs user-sensitive?
* Are the memory and storage requirements of the program within the limitations of the AFEMDEX computer?
* Is the program within the public domain?
* Is the communication protocol compatible with AFEMDEX?

To evaluate Modeling Programs only four questions need to be answered:

1. Do you want and need the program?
2. Does the program meet your needs?
3. Is the program available in FORTRAN source code?
4. Is the program within the capabilities of AFEMDEX in terms of memory, storage capacity and execution time?

If the answer is 'yes' to these questions then the program is of probable value to ATC.

Figure 1. AFEMDEX User Questionnaire

SECTION IV

CONCLUSIONS

A prototype AFEMDEX computer system has been developed and tested at an Air Force major command environmental planning office (HQ ATC/DEV). This system, incorporating the latest advances in microcomputer hardware and software technologies, has proven to be effective in accessing remote environmental data bases and simulation models. The prototype system can also handle up to nine users through its multiaccess operating system. The system is designed to be modular, permitting accommodation of additional users and hardware components.

The testing of the prototype AFEMDEX computer system can be termed only a partial success. This is caused by a relatively short testing period (3 months) and the limited number of environmental data bases and models available for testing. Available time during the testing period was devoted to personnel training; this proved to be a major effort since most Air Force personnel are not familiar with computer operations, programming, and applications. It is recommended that the Air Force identify additional data bases and models and allow for more personnel training, to take full advantage of the capabilities of the prototype AFEMDEX computer system. System testing reveals that it can offer users many benefits in terms of cost, manpower savings, and expanded technical capability.

SECTION V

RECOMMENDATIONS

A. RECOMMENDATIONS FOR SYSTEM IMPROVEMENT

The recommendations presented here are based on the analysis of user responses and observations made by AMI's staff. The testing and evaluation period revealed several potential areas for improvement. This section discusses the primary areas of concern and lists them in their order of priority.

1. PERSONNEL TRAINING

Additional personnel training is highly recommended for both military and civilian personnel. Military turnaround of personnel is high, making it necessary to train more than one individual as system operator. Availability of more than one operator reduces problems when an experienced operator is not available.

2. ENVIRONMENTAL CONTROL

During the test period, problems were encountered with the power supply being used by the AFEMDEX computer. Fluctuations in the power caused damage to both hardware and software contained within the AFEMDEX computer. Because of this, a power conditioner/uninterruptible power source should be installed as part of the AFEMDEX system.

For system efficiency and reliability, AMI further recommends that the AFEMDEX computer system be operated in a cool and dry environment. Ambient temperature should not exceed 85°F, and relative humidity 20 to 50 percent noncondensing.

3. MEMORY

The current system has only one RAM memory board (512KB), which must be used by both the operator and the users. Existing 512KB memory was proven adequate for test operations with up to three simultaneous users. Systems use beyond this level, however, will quickly become memory constrained and result in less than satisfactory system response. When the operator is compiling or linking a program, he must have at least 220 KB of memory. This severely limits the availability of memory to the users and therefore limits their operational capabilities. This limitation would be greatly reduced by a 512 KB memory board.

4. SOFTWARE

As discussed earlier, identification of usable software was a problem during the test period. It is recommended that the Air Force identify specific needs and then obtain a software specialist to locate or develop software to fulfill these needs. The software specialist could also be used to assist Air Force staff in evaluating and identifying the needs.

5. OPERATING SYSTEMS

Several operating systems are compatible with the AFEMDEX computer. As these systems become operational it may benefit the Air Force to have them evaluated for adapability, ease of use, and compatibility with current operations. Candidate operating systems include UNIX and MPM-86.

6. EDITOR

Comments made by ATC/DEV staff regarding the sensitivity and usability of the line editor and the fact that a majority of the staff's operating time is spent in the EDITOR mode, may warrant the change to a full-page editor. A full-page editor

capability could be made available for the AFEMDEX system. The full-page editor is more user-sensitive and allows easier operations. This would lead to substantial manpower saving and system efficiency improvement.

7. GRAPHICS

Based on user needs, it appears that graphics capabilities are needed to assist in the preparation of staff reports, architectural analysis, plus geographical and topographical information evaluation. Relatively inexpensive color pen plotters (less than $2000) are on the market. Such a plotter, coupled with existing software packages, can produce high-quality graphical displays.

8. REMOTE USERS

Access to AFEMDEX by remote users requires that the following procedures be followed on a routine basis:

a. Operational hours need to be desiqnated so that outside users will know when they can get onto the system.

b. A time period must be designated for compiling and printing programs.

c. The system operator must ensure that full system access is available.

d. Adequate RAM memory for remote and onsite users must be maintained during use period.

e. Remote users must remember to log off when their work is done

B. RECOMMENDATIONS FOR TECHNOLOGY TRANSFER

Appendix A tabulates the estimated costs of a computer system with capabilities similar to those of the prototype system currently installed at Randolph AFB. Compared to this prototype system, substantial savings in system software costs will be realized for additional systems. This cost avoidance will result from the relatively inexpensive charges that Intel requires for duplicating system software. It is estimated that an additional system will cost $52,000.

The same type of computer used in the AFEMDEX system located at HQ Air Training Command should be installed at other Air Force centers with modeling capabilities. This includes, but is not limited to, the Air Force Engineering and Services Center and Occupational and Environmental Health Laboratory.

It should be pointed out that the AFEMDEX prototype computer is not limited to environmental planning applications but can also be useful in fields that deal with data bases and mathematical models.

Vertical transfer plans depend greatly on the usage anticipated at each command. As long as the command has less than eight users at any one time, all that is needed is a number of remote terminals with phone modem hookup capability. More than eight simultaneous users would require another computer system. The alternative would be to upgrade AFEMDEX memory and expand the number of input ports. This would require an additional 512 KB memory board and an Intel 534 communication board with four additional ports. These two boards cost under $3000. Thus with little additional expenses, AFEMDEX would be capable to accommodate up to 12 users.

Vertical transfer, using remote terminals would normally occur within the same geographical area of the computer site to

keep long-distance telephone costs at a minimum. When command facilities are separated by great distances and each facility anticipates frequent application by only a few users, it would be better to install separate systems at each facility. With their networking capabilities, AFEMDEX computers can access and share data bases and models.

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APPENDIX A

ESTIMATED COSTS OF ADDITIONAL SYSTEMS

The AFEMDEX prototype computer system, as installed and operated at Randolph AFB, is the product of unique component integration to meet network computer operations.

To replicate the prototype system for use at other facilities, a cost estimate is provided. While these costs are only approximate, a tailored system, with down-scaled hardware resulting in lesser capacity, could be fielded at reduced price. Further, it is worth noting that commercial vendors have recently begun marketing multiuser computer systems with fundamental capabilities similar to the AFEMDEX prototype. These systems generally lack the floating-point speed for arithmetic operations and an efficient FORTRAN compiler. The use of Intel 8086 microprocessor and its 8087 arithmetic co-processor makes AFEMDEX one of the most powerful and cost-effective systems available for scientific applications.

[a] HARDWARE COMPONENTS:

Chassis & Power Supplies	$ 3,100
8086 CPU Board	$ 1,900
8087 Chip	$ 250
42MB Winchester Disk Drive & Controller	$ 9,200
2 Intel 534 I/O Boards	$ 1,750
2 8-inch Floppy Drives and Controller	$ 2,100
Qume QVT-102 Terminal	$ 750
Siemens 2712 Ink Jet Printer*	$ 3,200
Cipher Tape Drive**	$ 4,000
Tape Controller**	$ 2,400
512K Memory Board	$ 1,650
2 Hayes 1200 Smartmodems	$ 1,050

300-Baud Modem		$ 150
Rack		$ 650
Cables		$ 500
	SUBTOTAL :	$ 32,650

[b] SOFTWARE COMPONENTS

iRMX Incorporation Fee		$ 400
Fortran-86 Incorporation Fee		$ 800
PLM-86 Incorporation Fee		$ 400
	SUBTOTAL :	$ 1,600

[c] INTEGRATION LABOR

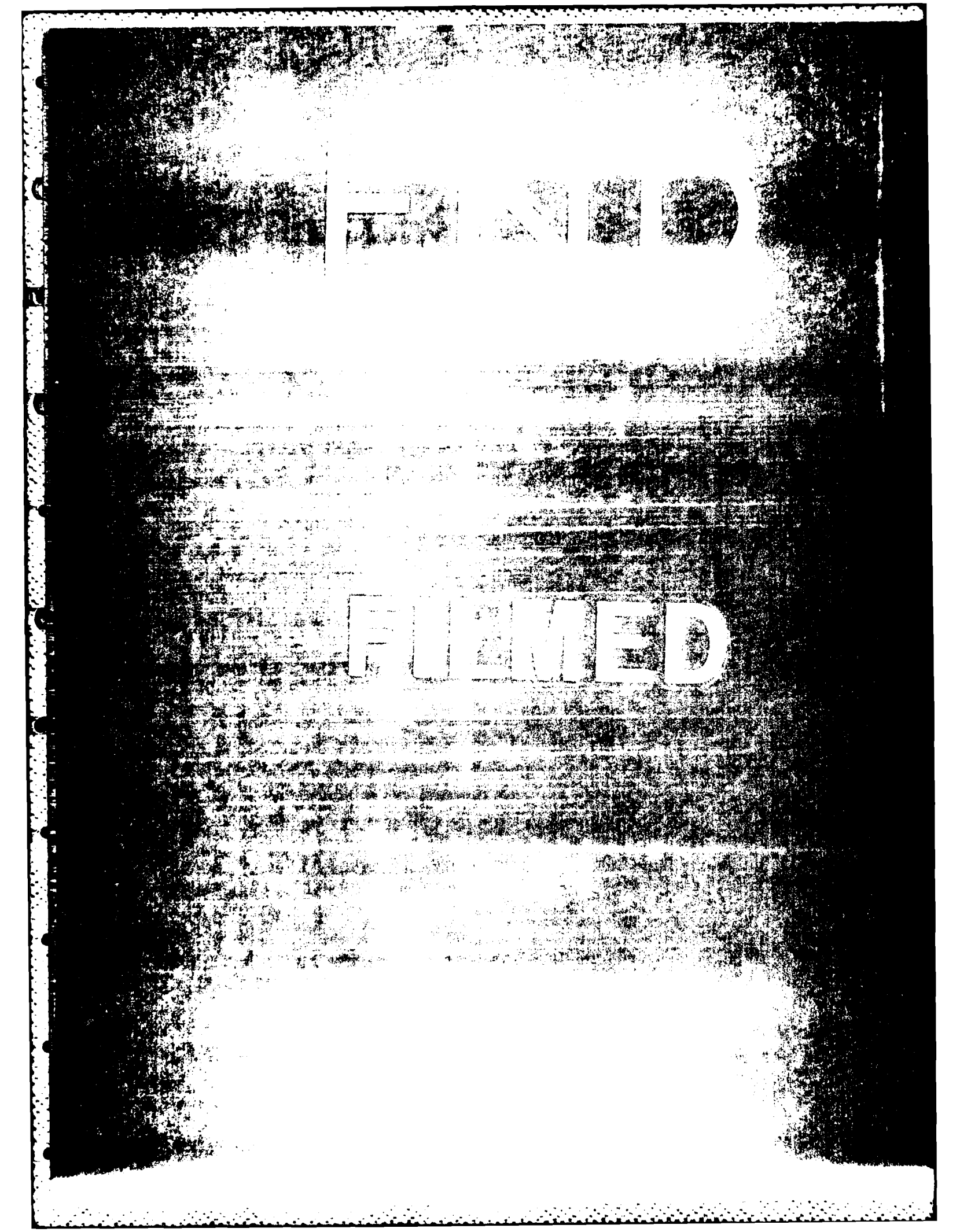
2 Engineers X 200 hours	$ 16,000

[d] MISCELLANEOUS (shipping,supplies) $ 1,500

TOTAL ESTIMATED COSTS : $ 51,750

* A down-scaled capability printer would cost approximately $1500.

** In a down-scaled system, this item could be eliminated.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